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Environmental Effects of Dredging
Technical Notes

PCDDF89--UPDATED COMPUTER MODEL TO EVALUATE CONSOLIDATION/DESICCATION OF SOFT SOILS

PURPOSE: This technical note describes a modified and updated version of the computer program Primary Consolidation and Desiccation of Dredged Fill (PCDDF). PCDDF was developed under the Dredging Operations Technical Support Program for use in evaluating the long-term storage capacity of confined dredged material disposal areas. The program accounts for both the consolidation and desiccation of compressible materials and has recently been modified to more accurately simulate layered field conditions which often exist in disposal sites. The modified computer program is called PCDDF89.

BACKGROUND: As a part of the planning and management activities associated with dredging of the Nation's navigable waterways, evaluations are periodically conducted to assess the disposal site capacity needs for storing dredged sediments. Such evaluations help identify shortfalls (both short-term and long-term) in existing containment area storage capacity; they may also be used to evaluate potential new disposal sites.

Storage capacity evaluations require quantification of the amount and rate of both primary consolidation and desiccation which will occur in the site of interest. A computer program was developed to predict surface settlement as a result of these two phenomenon (Cargill 1985). This program incorporates a finite (large) strain theory of consolidation and an empirical desiccation model. The original program was capable of accounting for placement of multiple lifts of dredged material at various points in time as well as for the consolidation and desiccation of the entire deposit. However, the original model could only handle one dredged material type and one foundation soil type.

With increased emphasis on the long-term management of dredged material disposal and the required development of long-term disposal plans (greater than 10 years), the need to accurately predict dredged material containment area site capacity has also increased. To assist Corps of Engineers elements in these planning efforts, PCDDF has been modified to account for multiple material types in both the dredged material and the foundation soils.

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Original Program

PCDDF simulates the filling and subsequent settlement due to consolidation and desiccation of multiple lifts of dredged material within a confined disposal facility; it also accounts for consolidation of a compressible foundation layer. The consolidation process is modeled by the finite strain theory of consolidation which accounts for the large deformations and nonlinear soil properties inherent in the very soft soils commonly encountered during maintenance dredging (Gibson, England, and Hussey 1967; Cargill 1985). The desiccation process is modeled using an empirical description of the water balance in the uppermost dredged material lift. The surcharge which results from the desiccated crust is accounted for in consolidation computations for the underlying lifts.

PCDDF uses an explicit finite difference solution at successive time steps for modeling the one-dimensional consolidation process, and it makes monthly adjustments in the top boundary condition and boundary location in accordance with the amount of consolidation and desiccation which have occurred. In addition to material settlement, which is calculated from the void ratio-permeability relationship, the program also calculates the stresses and pore pressures throughout the material deposit using the void ratio-effective stress relationship. Any sequence of varying dredged material disposal volumes as well as consolidation in an underlying foundation material can be considered. The original PCDDF model was limited to analysis of only one dredged material type, i.e., dredged material with one compressibility and one permeability relationship, although placement of numerous lifts of this material can be simulated; it can analyze only one compressible foundation soil layer.

The accuracy of the original PCDDF to simulate the settlement of dredged material due to consolidation and desiccation has been verified for a number of sites (Cargill 1985; Poindexter 1988). At all of these sites, predictions of surface elevation versus time were made and were compared to measured field data. Generally very favorable results were obtained. However, innovative approaches were sometimes necessary to bypass the limitation of one material type. For

example, sometimes samples of different materials to be placed into one disposal site would be combined before laboratory testing to provide "average" compressibility and permeability data. When one layer was significantly thicker than any others, the properties of the thick layer would often be assigned to the entire material thickness. In some cases when multiple thick compressible layers required analysis, superposition of settlement results for the various layers was used (Poindexter 1988).

Modifications

PCDDF has recently been modified by Stark (in preparation) to execute faster and to account for different types of foundation and dredged fill materials. PCDDF uses seven different interpolation routines to calculate various soil properties, such as stresses and pore pressures, at specified times. In a typical problem involving the behavior of a single layer of dredged fill, PCDDF will make 90,000 to 100,000 interpolations over 15 time steps. As a result, the interpolation routines had to be optimized before the multi-layer option could be effectively implemented. A "history-dependent" interpolation scheme was chosen so the interpolations were not required to start at the beginning of the soil property distribution, but at the point of the previous interpolation. The use of the history-dependent interpolation scheme resulted in a 20 to 25 percent increase in the execution speed of PCDDF.

PCDDF was also modified to allow the analysis of 10 different foundation layers and 25 different dredged fill materials. The same input is required for each material type as was required for the single-layer problem. In fact, the existing single-layer data files can be used in the new version of PCDDF by adding one parameter to the data file which indicates whether the problem is single- or multi-layer. If the parameter indicates single layer, the program will use the existing input and produce the same output as the older version of PCDDF but 20 to 25 percent faster. The multi-layer output has the same format as the original single-layer output except that the different material properties and the final void ratios, stresses, and pore pressures will be printed with a corresponding material identification number.

The ability to model the various types of foundation and dredged fill materials results in better predictions of the long-term capacity of confined

dredged disposal areas. The increased speed of PCDDF89 will also make the periodic capacity evaluations of the areas a more manageable task.

Other Applications

Although PCDDF was originally developed to assess settlement of very soft layers of dredged material in confined disposal facilities, it is also applicable to other compressible soil deposits. The finite strain consolidation theory used in PCDDF89 is applicable to soils ranging in compressibility from soft to firm and can be used for a variety of consolidation analyses including conventional one-dimensional analyses.

PCDDF can also properly be used to analyze soils located either above or below the water table. Since the program uses the principle of effective stress, it will accurately analyze subaqueous soil deposits such as in-situ bottom soils and dredged material deposits. Although PCDDF is a one-dimensional program, it has been used successfully to analyze subaqueous mounds of dredged material with side slopes of approximately 1.5 to 5H:100V (Poindexter 1988).

Availability

PCDDF89 will execute on any IBM-compatible microcomputer containing 640 kilobytes of random access memory. It is highly recommended, but not required, that the computer have a math coprocessor chip and a hard disk. The data can be entered into the program interactively or through a data file. The program's output can be stored in a file, sent to a printer, or displayed on the screen. A comprehensive user's guide which accompanies the program describes in detail the mathematical model and the various input and output options. PCDDF89 will be incorporated into the Automated Dredging and Disposal Alternatives Management System (ADDAMS) in the near future (Schroeder 1988). At present, the old version is available under ADDAMS.

References

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